

An Ecosystem Framework for the Management of Musquash Estuary Marine Protected Area

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by

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LIST OF ABBREVIATIONS

ASEC	Aquaculture Site Evaluation Committee
ATVs	All Terrain Vehicles
BoF	Bay of Fundy
BIO	Bedford Institute of Oceanography
CCME	Canadian Council of Ministers of the Environment
CEM	Continuous Emissions Monitoring
CFIA	Canadian Food Inspection Agency
CMA	Coastal Management Area
CMPs	Conservation Management Plans
DA&F	New Brunswick's Department of Aquaculture & Fisheries
DELG	New Brunswick's Department of Environment & Local Government
DFO	Fisheries and Oceans Canada
DNRE	New Brunswick's Department of Natural Resource & Energy
EC	Environment Canada
ECW	Eastern Charlotte Waterways
EOs	DFO's National Ecosystem Objectives for Management
HADD	Harmful Alteration, Deterioration or Destruction
IFMPs	Integrated Fishery Management Plans
ISO	International Organization for Standardization
LTRA	Long-Term Reference Area for rockweed
MPA	Marine Protected Area
NB	Province of New Brunswick
RAP	Regional Advisory Process
SARA	Species at Risk Act
SCEM	Software Continuous Emission Monitoring

ABSTRACT

SINGH, R. and M.-I. BUZETA. 2007. An Ecosystem Framework for the Management of Musquash Estuary Marine Protected Area. Can. Tech. Rep. Fish. Aquat. Sci. 2702. v + 27 pp.

This report presents an ecosystem framework for the management of Musquash Estuary Marine Protected Area (MPA). The Musquash Planning Group (later called the Musquash Advisory Committee) identified specific goals and objectives for the MPA. These objectives were used in further defining specific ecosystem objectives for the MPA based on the national ecosystem objectives developed by the Department of Fisheries and Oceans (DFO). The Musquash ecosystem objectives, like the national ecosystem objectives, cover three broad categories – biodiversity, productivity and habitat. In defining these objectives (and their sub-objectives) the approach was to look at the present and allowed human activities within the MPA and to develop operational strategies that would target the possible impacts of those activities. The framework further points to the possible performance indicators that can be used to monitor how well those objectives are being met. This report provides a summary of the relevant federal and provincial regulations that would be relevant to the human activities within the MPA. The present human activities are described and their relevance to the ecosystem framework, to monitoring, and to the management of the MPA are described.

RÉSUMÉ

SINGH, R. et M.-I. BUZETA. 2007. « An Ecosystem Framework for the Management of Musquash Estuary Marine Protected Area », *Rapport technique canadien des sciences halieutiques et aquatiques*, 2702, v + 27 p.

Ce rapport présente un cadre de gestion écosystémique pour la zone de protection marine (ZPM) de l'estuaire de la Musquash. Le Groupe de planification de la Musquash (ultérieurement rebaptisé *Comité consultatif de la Musquash*) a cerné pour la ZPM des buts et des objectifs qui, à leur tour, ont servi à définir de façon plus détaillée les objectifs à établir pour la gestion écosystémique de la ZPM, à la lumière des objectifs écosystémiques nationaux élaborés par le ministère des Pêches et des Océans (MPO). À l'instar des objectifs nationaux, les objectifs établis pour l'estuaire de la Musquash se classent dans trois grandes catégories – la biodiversité, la productivité et l'habitat. Pour définir ces objectifs (et les sous-objectifs qui y sont rattachés), l'approche adoptée consistait à examiner les activités humaines actuellement autorisées dans la ZPM et à élaborer des stratégies opérationnelles qui en ciblent les impacts possibles. Le rapport traite également des indicateurs de rendement susceptibles d'être utilisés pour surveiller l'atteinte des objectifs. En outre, le document présente sommairement les règlements fédéraux et provinciaux qui s'appliquent aux activités humaines dans la ZPM; il décrit ces activités et montre leur pertinence pour le cadre écosystémique, la surveillance et la gestion de la ZPM.



INTRODUCTION

This document describes an ecosystem framework for the management of the Musquash Estuary Marine Protected Area (MPA) and identifies the monitoring requirements. The aim of this document was to develop the operational objectives and strategies, along with the performance indicators for the MPA, and to identify the monitoring that would be needed to determine if those objectives were being met. A summary is presented of similar efforts for other areas being managed, or being designated, as MPAs within Canada. Most of the current areas designated as MPAs do not have completed management plans; however, information was made available in draft form. The approach for each site varies, but Table 1 summarizes the strategies, objectives and monitoring under consideration for each area. It is important to note that while the management plan for the Gully MPA is well advanced, none of the coastal MPAs have developed detailed ecosystem-based management plans as is being attempted here.

At a DFO national workshop on objectives and indicators, three overarching Ecosystem Objectives (EOs) were identified for operationalizing ecosystem-based management (Jamieson et al. 2001). The workshop focused on the development of conceptual conservation objectives relating to biodiversity, productivity, and physical and chemical properties of the ecosystem. Using these broad guidelines Gavaris et al. (2005) developed an ecosystem-based framework for managing Canadian fisheries on Georges Bank by considering it from the human activities point of view. Fishing activities, as the major human activity on Georges Bank, featured prominently in the framework for ecosystem-based management for the area (Gavaris et al. 2005). While these documents provide the basis for the development of the ecosystem framework for Musquash MPA, the approach encompasses several human activities that do not impact off shore areas. For these reasons, the ecosystem framework for Musquash is unique since there are no precedents for such a framework in a coastal area. In developing the Musquash operational strategies and objectives, previous work on the framework as described in Singh and Buzeta (2005) was taken into consideration.

Using the three overall ecosystem objectives for Musquash Estuary, a series of sub-objectives and operational strategies, along with the relevant performance indicators, were identified for each set of human activities occurring within the Estuary (Table 2). Most of the present human activities within the Estuary are expected to continue and will be managed according to the present regulatory provisions (Table 3). Using the identified performance indicators for the ecosystem sub-objectives, a series of monitoring requirements were identified. These would form the basis for the Musquash Estuary monitoring plan (Table 4). Data for some of the indicators are already known, while others need to be set in order to recommend end points. In the case of new or unforeseen activities, these would also be evaluated against the ecosystem objectives for Musquash, as shown in Table 2, ensuring that the ongoing monitoring plan (Table 4) and identified reference points are not lacking.

The identified ecosystem objectives, sub-objectives, operational strategies, performance indicators, and monitoring requirements will form the basis for the ecosystem management component of the larger MPA management plan. The management plan will include the broader aspects of management: the management framework that identifies the roles and responsibilities of the various overlapping jurisdictions; the regulatory framework; the management of the larger watershed surrounding the MPA; the role of community involvement; an educational strategy; and any research requirements. The ecosystem framework being developed here will feed into this larger management plan, providing guidance to managers making decisions on day to day issues, new proposals and developments, and managing ongoing activities.

PLANNING GROUP OBJECTIVES FOR THE MUSQUASH MPA

VISION AND OBJECTIVES FOR THE MUSQUASH MPA

The community vision (overall objective) for the Musquash Estuary MPA initiative is "the protection and restoration of the Musquash Estuary and surrounding Salt Marshes" and the primary management goal is "to have activities better regulated, and that existing laws and regulations should be followed" (Musquash Estuary MPA Planning Group). This is elaborated in the management plan for the Musquash Estuary MPA, which states that "the objective is to limit or avoid disturbance, damage or destruction due to the direct influence of human activities". The *Musquash Estuary MPA Regulations* (Canada Gazette Part II, Vol. 140, No. 26, 2006) reflect this objective by prohibiting the disturbance, damage, destruction or removal of any living marine organism or any part of its habitat, while exceptions are made for a list of activities that include, for example, fishing and maintenance of wharves and navigational channels. The intent is to maintain biodiversity and ecosystem function of the area, including the highly productive mudflats, salt marshes, and estuary. Complementary efforts in the surrounding shoreline and watershed by the Province of New Brunswick and stakeholders will also contribute to the achievement of conservation objectives.

The objectives developed by the original Musquash Estuary MPA Planning Group were:

- Maintaining biodiversity of the area
- Maintaining a healthy fishing industry
- Protecting this highly productive habitat
- Increasing natural habitat and bird life in the marsh and surrounding land
- Preserving the area for future generations
- Ensuring conservation and sustainable use of the marsh

Table 1. Comparison of objectives, strategies and proposed monitoring research in Canadian Marine Protected Areas.

Ecosystem Objective	Operational strategy	Operational Objective	Monitoring Research
Basin Head: <i>conservation and protection of the Lagoon ecosystem including the unique form of Irish moss currently present and to maintain and enhance the ecosystem</i> - To maintain and enhance the quality of the ecosystem - To maintain a viable population of the Basin Head strain of Irish moss - Provide the public with an understanding of Irish moss and ecosystem - To ensure that any potential economic benefit offered by this plant is not lost by destruction of this small unique ecosystem - To conserve and protect the lagoon ecosystem through ongoing management, including use of regulations - To provide for the "multiple use" of the ecosystem with activities that meet the ecological objectives			
Productivity	To reduce impacts on water quality	Determine levels of soluble N, Ph and chlorophyll A within lagoon	Basin/Lagoon Water Sampling program
Productivity	To reduce impacts on water quality	In-stream water quality monitoring Determine levels of soluble organic and inorganic N and Ph in streams	Watershed monitoring
Habitat	To minimize bottom disturbance		
Habitat & Productivity	To eliminate any removal and disturbance of Irish moss and productivity	Eliminate the removal and disturbance of Irish moss and productivity	<i>Chondrus</i> Bed Surveys
Productivity	To prevent over-harvesting of any harvested species	Determine open/close status for safe shellfish harvest	Canadian Shellfish Sanitation Program
Biodiversity	To minimize threats to biodiversity	Index of species richness and diversity	Community Aquatic Monitoring Program (CAMP) monitoring
Gilbert Bay: (1) the conservation and protection of the Gilbert Bay cod population and its habitats (2) the conservation and protection of the Gilbert Bay ecosystem			
Productivity	To maintain environmental health	Eliminate factors causing poor environmental health	Monitoring of the William's Harbour sewage outfall for environmental quality
Habitat & Productivity	To maintain environmental health	Eliminate potential effects on cod by runoff	Monitoring specific parameters associated with the spring runoff from two rivers
Habitat	To maintain habitat	No significant loss of habitat	Visual examination of bottom

Ecosystem Objective	Operational strategy	Operational Objective	Monitoring Research
			habitat
Habitat	To maintain water quality	No visible surface oil slick or floating litter	Visual examination of surface water
Habitat	To maintain water quality	No significant degradation of water quality	Visual examination of water column for plume
Habitat	To maintain water quality	No offensive odour	Note intensity of odour on scale of 1-10
Habitat	To maintain water quality	No significant degradation of water quality	Monitor water quality using YSI Sonde at outfall and at reference sites
Productivity	To maintain the cod population	Maintain cod population	Annual sampling and tagging program of cod (beach seining)
Biodiversity	Maintain biodiversity of larval species	Maintain larval species	Larval surveys (duration uncertain)
Biodiversity	Maintain biodiversity finfish species	Maintain finfish species	Beach seining survey for monitoring finfish biodiversity
Productivity	Maintain abundance of scallops	Maintain scallop fishery	Logbook monitoring proposed
Productivity	Ecosystem carrying capacity estimate	Estimate carrying capacity of ecosystem	Proposed study on ecosystem carrying capacity for finfish
The Gully: Ecosystem Objectives: - Maintain ecosystem components - maintain communities within bounds of natural variability - maintain species within bounds of natural variability - maintain populations (genetic diversity), within bounds of natural variability - Maintain ecosystem component function - maintain primary production within bounds of natural variability - maintain trophic structure so that individual species/stages can play their natural role in the food web - maintain mean generation times of populations such that population resiliency is assured - Maintain ecosystem physical and chemical properties - conserve critical landscape/seascape features and water column properties - conserve water, sediment and biota quality			

Ecosystem Objective	Operational strategy	Operational Objective	Monitoring Research
Biodiversity & Habitat	Maintaining cetacean populations	Maintain cetacean populations within the bounds of natural variability	Status of northern bottlenose whale population (use of The Gully). Interactions of cetaceans with fishing gear (#s of incidents). Interactions of cetaceans with shipping. Interactions of cetaceans with activities related to petroleum exploration and development. Interactions of cetaceans with military exercises
Habitat	Maintaining benthic habitat	Maintain benthic habitat within the bounds of natural variability	Interaction of fishing gear with benthic communities
Productivity & Habitat	Maintain fish populations	Maintain a fish populations and a productive fisheries	Fisheries interactions with non-target species Fisheries disturbance to benthic habitat of The Gully (impacts on different habitat types).
Biodiversity	Maintain bird species	Maintain the use of the area by bird species	Interaction of seabirds and other non-target species with fishing gear. Status of seabird populations that use The Gully.
Habitat	Maintain a healthy habitat	Eliminate/reduce contaminants	Monitor for particular invasive Monitor for levels of particular contaminants Analysis of these fish for health and contaminant build up
Bowie Seamount: Could not locate documents that spell out the objectives.			
Endavour Hot Vents: Could not locate documents that spell out the objectives.			

References:

Basin Head: R. MacIsaac, I. Frenette (M.-I. Buzeta, pers. com. 2006). Basin Head Operational Management Plan Draft, August 2005.
Gilbert Bay MPA NFD: N. Wells, J. Simms. (M.-I. Buzeta, pers. com. 2006). Gilbert Bay MPA NFD, August 2005, Draft V1.
Gully MPA: Breeze et al. (2002), Worchester (2006)

MPA OBJECTIVES WITHIN THE CONTEXT OF DFO'S NATIONAL ECOSYSTEM OBJECTIVES FOR ECOSYSTEM-BASED MANAGEMENT

Objectives developed by the Musquash Estuary MPA Planning Group were:

- Maintaining biodiversity of the area - This objective clearly falls under the ecosystem objective of **Biodiversity**.
- Maintaining a healthy fishing industry - This objective implies that the species harvested presently should continue to be productive and healthy. This would include clam, herring, lobster, periwinkle, eel, elver, scallop and dulse. This objective is very broad and would be covered by the ecosystem objective of **Productivity**. Species that spend part of their life cycle in the MPA (and are the target of a fishery) would benefit if the ecosystem objective of **Biodiversity** was met. It is important to note, however, that for part of their life cycle, some harvested species may depend on habitats or processes outside the boundaries of the MPA and this may influence their abundance.
- Protecting this highly productive habitat - This objective is clearly covered by the ecosystem objective of **Productivity**. However, a healthy **Habitat** would also be productive.
- Increasing natural habitat and bird life in the marsh and surrounding land - This objective is very broad and would be achieved by the ecosystem objective of **Habitat**. Natural habitat can be increased by restoration projects. If habitat is increased, then the objectives of **Biodiversity** and **Productivity** would also be relevant. If these three ecosystem objectives are achieved, then this objective would be covered.
- Preserving the area for future generations - This objective would be best covered by the ecosystem objective of **Habitat**. If **Biodiversity** and **Productivity** were maintained in the MPA, however, this objective would also be achieved.
- Ensuring conservation and sustainable use of the marsh - This objective would met by the ecosystem objectives of **Habitat** and **Productivity**. In this case, achieving the two ecosystem objectives of **Habitat** and **Productivity** would also mean that the ecosystem objective of **Biodiversity** would be met.

These ecosystem objectives must take into account each of the eight ecotypes found within the Musquash Estuary MPA: rocky intertidal substrate, tidal pools, sand and gravel intertidal beaches, mudflats, salt marsh, pannes within salt marsh, subtidal soft substrate, and subtidal hard substrate as described in Singh et al. (2000).

PROPOSED ECOSYSTEM OBJECTIVES

The ecosystem objectives for Musquash Estuary MPA were developed following the guidelines developed for the DFO's national ecosystem objectives for ecosystem-based management (Jamieson et al. 2001) which takes into consideration the objectives of sustainability of human usage of environmental resources, and the conservation of species and habitats. Additionally, the ecosystem objectives for Musquash Estuary were developed following the ecosystem framework proposed by Gavaris et al. (2005) as applied to the Canadian fisheries on Georges Bank. For Musquash Estuary MPA, the three overarching ecosystem objectives developed are as follows:

Maintaining Biodiversity - *ensure no unacceptable reduction in biodiversity by maintaining enough components (ecotypes, communities, populations, and species) to preserve the structure and natural resilience of the ecosystem.*

Maintaining Productivity - *ensure no unacceptable reduction in productivity of each component (primary, community, population) so that it can play its role in the functioning of the ecosystem.*

Maintaining Structure of the estuary and marsh ecosystem (Habitat) - *ensure no unacceptable modification of habitat that is difficult or impossible to reverse in order to safeguard the physical and chemical properties of the ecosystem.*

With these three overarching objectives in mind, the sub-objectives, operational strategies and performance indicators were detailed for the Musquash Estuary MPA. The initial approach was to document the human activities and then consider their possible impacts on the stated ecosystem sub-objectives. Once those impacts were identified, the performance indicators were selected based on what would be considered as measurable factors that directly relate to those impacts. The ecosystem objectives and sub-objectives, as they relate to human activities, along with the performance indicators, are presented in Table 2.

It is recognized that the challenge is to define the measurable indicators and a cost-effective monitoring program that relate to the ecosystem objectives and the reference points (Gislason et al. 2000). In Table 2, the human activities that are presently occurring within the Estuary were examined to determine their possible impacts as they relate to the identified ecosystem sub-objectives. The corresponding performance indicators are intended to identify the measurable variables that would assist in determining whether those objectives were being met. These performance indicators may be altered if and when experience indicates that they are not the best variables to measure how well the ecosystem objectives are being achieved. In Table 3, the regulatory frameworks that are presently in place for these activities are presented. These regulations will guide the implementation of any present and future monitoring requirements.

Table 2. The Ecosystem Objectives of (A) Biodiversity, (B) Productivity, and (C) Habitat, Operational strategies, Performance indicators and related Human Activities in the Musquash Estuary MPA [based on Jamieson et al. (2001) and Gavaris et al. (2005)].

(Fisheries related - scallop, lobster, herring shut-off, aquaculture, recreational fisheries for clams, periwinkles, dulse; Recreation, Tourism & Research - boating, jet skiing, ATVs, human presence and trails; Watershed & Coastal Influences - organic enrichment, run off from land, pollution; Climate change - dependent on tolerance of species)

(A) BIODIVERSITY – ensure no unacceptable reduction in biodiversity by maintaining enough components (ecotypes, communities, populations, species) to preserve the structure & natural resilience of the ecosystem.

Sub-Objective	Operational strategy	Performance Indicator	Fisheries related	Human Activities in the Musquash MPA				
				Coastal Structures & Development - including dredging	Transportation - commercial boating	Recreation, Tourism & Research	Watershed & Coastal influences	Climate change
<u>Ecotypes</u>	Limit unacceptable modification of, or reduction in, each ecotype	% area of Estuary ascribed to each ecotype in each zone & location in Estuary	Disturbance and damage to benthic species and resulting in changes to ecotypes	Loss due to smothering/hindering growth & reproduction	Disturbance to predators from noise and/or human presence resulting in changes to ecotypes	Loss due to trampling or abrasion	Changes in community structure due to increase growth of opportunistic species and resulting in changes to ecotypes	Changes due to increase in temps
<u>Community</u>	Maintain trophic level balance	Number of species in each trophic level & abundance of keystone species	Decrease due to scallop or lobster removal & removal or damage of non-target species	Changes in benthic community structure	Disturbance to predators from noise and/or human presence	Disturbance from noise and/or human presence	Changes in community structure due to increase growth of opportunistic species	Changes due to increase in temperature
	Minimize spread and impact of invasive species	Numbers and distribution of exotic species in Estuary in relation to Regional data	Disturbance provides opportunities for successful establishment of invasive species	May provide new substrates for establishment of invasive species	Introduction of exotics	Introduction of exotics	Not relevant	Introduction or spread of exotics
<u>Population</u>	Maintain spawning and breeding components of utilized species	Numbers of distinct viable populations for a species within the Estuary	Reduction in community diversity due to loss of populations	Loss due to low/high flow rate or exposure	Decrease in birds & mammals due to visual presence	Disturbance from noise and/or human presence	Changes in composition or density of benthic or pelagic species	Not relevant
	Rebuild local populations at risk	Number of local populations at risk	Decrease due to scallop or lobster removal & removal or damage of non-target species	Changes in benthic community structure due to loss of populations	Decrease in birds & mammals due to visual presence	Disturbance from noise and/or human presence	Changes in composition or density of benthic or pelagic species	Not relevant
<u>Species</u>	Maintain numbers of species within each ecotype	Number of species within each ecotype	Decrease due to scallop or lobster removal & removal or damage of non-target species	Changes in benthic community structure due to loss of species	Decrease in birds & mammals due to visual presence	Disturbance from noise and/or human presence	Changes in composition or density of benthic or pelagic species	Loss due to "coastal squeeze" – no room for landward expansion
	Keep numbers of opportunistic species to undisturbed levels	Ratio of opportunistic species to other species	Removal or damage of non-target species	Changes in benthic community structure due to loss of species	Decrease in birds & mammals due to visual presence	Disturbance from noise and/or human presence	Changes in species and/or community structure due to increase growth of opportunistic species	Not relevant
	Limit incidental mortality	% bycatch, absolute bycatch, bycatch mortality rate, abundance of impacted species	Disturbance and damage to non-target species	Changes in benthic species composition	Not relevant	Disturbance from noise and/or human presence	Loss due to low replacement	Loss due to "coastal squeeze" – no room for landward expansion

(B) PRODUCTIVITY - ensure no unacceptable reduction in productivity of each component (primary, community, population) so that it can play its role in the functioning of the ecosystem.

Sub-Objective	Operational strategy	Performance Indicator	Human Activities in the Musquash MPA					
			Fisheries related	Coastal Structures & Development - including dredging	Transportation - commercial boating	Recreation, Tourism & Research	Watershed & Coastal influences	Climate change
<u>Primary</u>	Limit harvest of primary producers & alteration of nutrients & water clarity affecting primary production	Percent of primary biomass harvested. Essential nutrient concentrations, historic water turbidity and phytoplankton concentration	Increase in turbidity from re-suspended sediments	Increase in turbidity from re-suspended sediments	Not relevant	Smothering or damage of individuals due to trampling or abrasion	Changes in species and/or communities due to increase growth of opportunistic species; phytoplankton blooms	Not relevant
<u>Community</u>	Limit removals/loss from any trophic level with respect to trophic demands of higher levels	Trophic levels present in each ecotype & estimates of biomass & spatial distribution	Decrease due to scallop/lobster removal & removal/damage of non-target species	Decrease due to loss of individuals & changes in community	Decrease in predators (birds & mammals) due to visual presence	Decrease in birds due to visual presence	Changes in communities due to increase growth of opportunistic species	Not relevant
	Limit total removals by human activities within the production capacity of the ecosystem system	Total catch biomass for harvested species	Decrease due to scallop/lobster removal & removal/damage of non-target species	Decrease due to loss of individuals & changes in community and populations	Not relevant	Not relevant	Not relevant	Increase due to higher temps
<u>Population</u>	Keep exploitation moderate	Mortality rate from fishing and hunting activities	Decrease due to scallop/lobster removal	Not relevant	Not relevant	Not relevant	Reduced growth/repro due to pollution/smothering	Not relevant
	Keep destruction/death of non-target individuals from each ecotype to a minimum	% bycatch; bycatch mortality rate; absolute bycatch, abundance of impacted species	Removal/damage of non-target species from fishing activities	Decrease due to loss of individuals & changes in populations	Not relevant	Smothering or damage of individuals due to trampling or abrasion	Not relevant	Not relevant
	Permit sufficient spawning biomass to evade exploitation or disturbance	Estimates of numbers of juvenile fish & bird hatchlings occurring in the Estuary	Decrease due to scallop/lobster removal	Smothering/damage of individuals	Decrease in predators (birds & mammals) due to visual presence	Not relevant	Not relevant	Not relevant
	Promote rebuilding when biomass is low	Estimates of biomass changes	Decrease due to scallop/lobster removal	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant
	Manage the size/age/sex of individuals captured or destroyed due to human activities	% size/sex/age in catch & in areas impacted by activities	Decrease due to scallop/lobster removal	Smothering or damage of individuals	Not relevant	Smothering or damage of individuals due to trampling or abrasion	Not relevant	Not relevant
	Prevent disturbance during spawning or nesting	Estimates of human use/presence based on monitoring of all activities	Damage to individuals	Decrease due to loss of individuals & changes in community and populations	Disturbance from noise and/or human presence	Disturbance from noise and/or human presence	Not relevant	Not relevant
	Manage discarding	Discarded catch	Removal or damage of non-target species	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant

(C) HABITAT – ensure no unacceptable modification of habitat that is difficult or impossible to reverse in order to safeguard the physical and chemical properties of the ecosystem.

Sub-Objective	Operational strategy	Performance Indicator	Human Activities in the Musquash MPA					
			Fisheries related	Coastal Structures & Development including dredging	Transportation - commercial boating	Recreation, Tourism & Research	Watershed & Coastal Influences	Climate change
<u>Bottom</u>	Reduce/control activities that result in physical disturbance of substrates and natural habitats	Area ascribed to different habitats (pelagic, benthic, nursery, spawning, migration pathways, marsh) and the % area and/or frequency disturbed/lost	Changes in habitat due to abrasion/physical disturbance & displacement by scalloping & clamming	Disturbance/loss of substrate and habitat due to dredging, construction, land reclamation; loss of benthic integrity	Boating may churn up substrates & creates wakes disturbing muddy and sandy substrates and habitats	Changes due to changes in ecological integrity	Eutrophication leading to deoxygenation	Loss due to "coastal squeeze" – no room for landward expansion; ↑ temperatures result in ↑ metabolic activities
	Maintain natural habitats and where possible increase the availability of natural habitats by restoration activities	Area ascribed to different natural habitats (pelagic, benthic, nursery, spawning, migration pathways, marsh)	Changes in habitat due to abrasion/physical disturbance & displacement by scalloping & clamming	Disturbance/loss of substrate and habitat due to dredging, construction, land reclamation; loss of benthic integrity	Boating may churn up substrates & creates wakes disturbing muddy and sandy substrates and habitats	Changes in habitat due to changes in ecological integrity	Eutrophication leading to deoxygenation and loss of habitat	Loss due to "coastal squeeze" – no room for landward expansion; ↑ temperatures result in ↑ metabolic activities
<u>Sediment and biota quality</u>	Minimize contaminant loads in sediment and toxic bio-accumulation in biota	Contaminant levels in sediment and bio-accumulated toxic levels in biota	Release of toxic residues from sediment due to disturbance	Addition or release of toxic residues from sediment due to disturbance	Release of toxic residues from sediment due to disturbance	Release of toxic residues from sediment due to disturbance	Input of toxic contaminants due to activities on land	Temperature ↑ resulting in ↑ stress levels and the exhibition of toxic influences in biota
<u>Biogenic Structure</u>	Minimize destruction or alteration to biogenic structure	% area ascribed to species providing biogenic structure	Changes due to abrasion or physical disturbance & displacement	Loss of species or damage to existing ones	Disturbance of substrates causing smothering and loss	Abrasion/physical disturbance	Changes in community structure due to increase growth of opportunistic species	Shifting of habitat due to higher sea levels
<u>Water column</u>	Minimize activities that result in changes in suspended solids	Water turbidity levels	Increase in turbidity	Increase in turbidity	Increase in turbidity	Increase in turbidity	Increase in turbidity	Not relevant
	Limit pollution from chemicals, deleterious changes in dissolved oxygen & eutrophication	Water quality levels	Not relevant	Not relevant	Pollution from boat engines and litter	Pollution from hydrocarbon-powered engines and litter	Loss due to contamination from chemicals, heavy metals & hydrocarbons	Not directly relevant but engines contribute to greenhouse gases & climate change
	Reduce/control activities that result in changes in hydrologic regime	Physical & biological features that influence the hydrologic regime	Not relevant	Loss due to change in hydrological/tidal range & flow rate or exposure	Not relevant	Compaction resulting in decreased aeration and water exchange	Not relevant	Shifting of habitat due to higher sea levels

REGULATIONS RELEVANT TO THE HUMAN ACTIVITIES

The *Musquash Estuary MPA Regulations* (Canada Gazette Part II, Vol. 140, No. 26, 2006) provide details on the designated management zones within the Estuary and detail the fishing activities that are expected to continue in the Estuary. Generally, Zone 1 (Fig. 1) is the area above Five Fathom Hole, and is considered the most sensitive and afforded the highest protection. Zone 2A is the area from Five Fathom Hole to the inner limit of the scallop zone (Zone 3) and Zone 2B is the Gooseberry Cove area (Fig. 1). Low impact activities are permitted in Zone 2 (A and B), while a greater number of activities will be permitted in Zone 3. In addition to the *Musquash Estuary MPA Regulations*, all human activities within the MPA will be regulated by relevant provincial or federal regulations. Table 3 provides a summary of some of the most relevant regulations contained in acts, policies, licenses and management plans. Some of these human activities are already being monitored under existing regulatory provisions; however, within the Estuary these activities will need to be monitored closely. This may entail changing the reporting requirements for some activities and the implementation of better data gathering techniques.

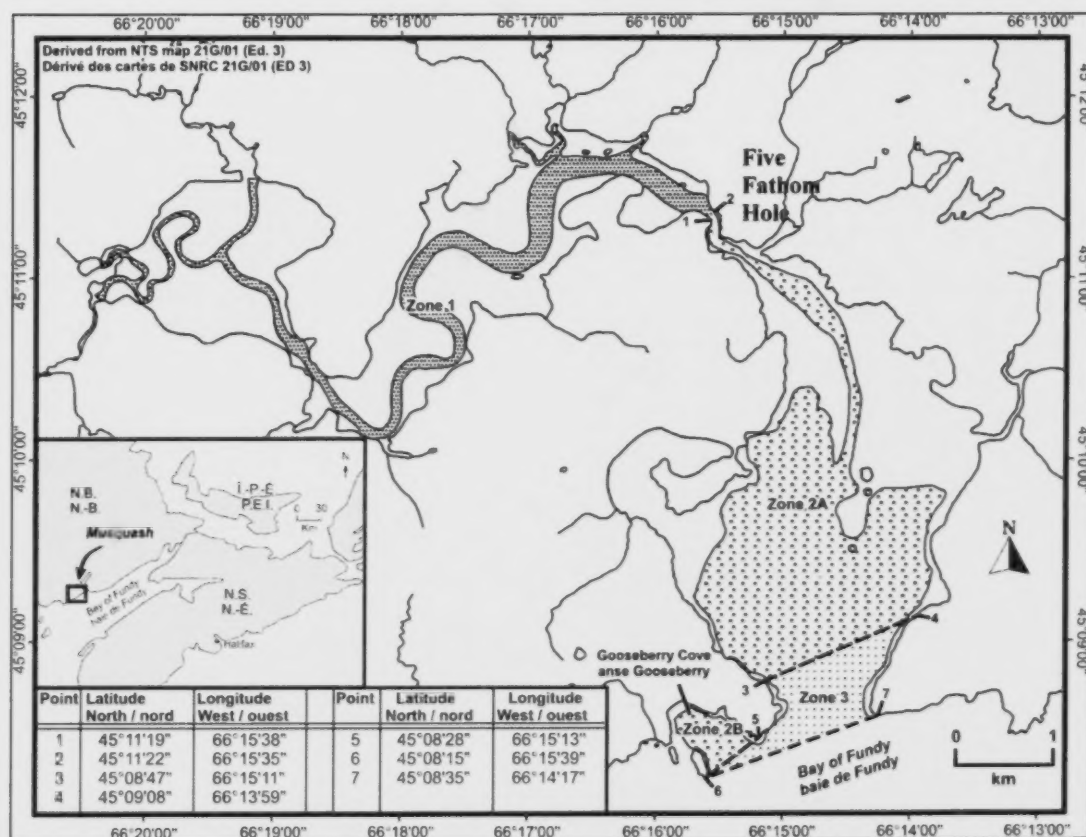


Fig. 1. Map of the Musquash Estuary MPA showing the different management zones. Zone 1 is the afforded highest protection, in Zone 2A and 2B low impact activities are permitted and in Zone 3 scalloping will continue and a greater number of other activities are permitted.

Table 3. Managed Activities in Musquash Estuary and their regulatory provisions (and other relevant monitoring) as they relate to the identified performance indicators.

Performance Indicator	Fisheries related	Performance Indicator	Coastal Structures & Development	Performance Indicator	Transportation
Total catch biomass, % bycatch, bycatch mortality, absolute bycatch abundance of impacted species, discarded catch, estimates of biomass changes, % size/sex/age in catch and in areas impacted by activities	<i>Fisheries Act</i> – restrict activities that cause harmful alteration exceptions under MPA regulations for scalloping in Zone 3 and lobstering in Zones 2 & 3 (Fig. 1). <i>Atlantic Fishery Regulations, 1985</i> and the <i>Maritime Provinces Fishery Regulations</i>	Physical and biological features that influences the hydrologic regime, water quality levels, areas ascribed to different habitats - caused by direct or indirect disturbance of marsh & subtidal habitats	NB Coastal Policy guides coastal developments; NB Wetland Conservation Policy guides wetland protection. Any construction within 30 metres of a wetland requires a <i>NB Watercourse and Wetland Alteration</i> permit. <i>Navigable Waters Protection Act, Fisheries Act & NB Clean Water Act</i> will guide, maintenance, repair and removal of bridges	Water quality levels, ratio of opportunistic species to other species, numbers & distribution of exotics – all can be influenced by bilge discharges	Bilge discharges – regulated by Transport Canada, reported to Environment Canada?
Mortality rates from fishing activities for each trophic level, total catch biomass, spatial distribution, bycatch, abundance of impacted species in each ecotype	IFMPs and CMPs – regulate & manage fisheries. Presently no specific monitoring of catches within the MPA. May require special provisions in licenses/plans	Trophic levels in each ecotype, estimates of biomass and spatial distribution, areas ascribed to different habitats	Dredging & disposal of spoil regulated by EC under the <i>Can. Environ. Protection Act</i> ; DFO's HADD regulations under the <i>Fisheries Act, NB Clean Water Act & Navigable Waters Protection Act</i>	Water quality levels, area ascribed to different habitats /ecotypes	<i>Canada Shipping Act</i> regulates oil pollution from vessels – any discharge from vessels that results in a harmful effect on habitat
Number of local populations or species at risk	SARA will apply if there is a species at risk	Number of local populations or species at risk	SARA will apply if there is a species at risk		
Percent of primary biomass harvested	Rockweed harvesting managed/licensed by DA&F guided by RAP. No harvesting is planned within Musquash; this is written into management plan	Area covered by ecotypes present in the Estuary, essential nutrient concentrations, water turbidity levels and phytoplankton concentration	Large developments trigger regulations under the <i>NB EIA-Clean Environment Act</i>		
Number of species in each trophic level & abundance of keystone species	<i>NB Aquaculture Act</i> regulates permitting, guided by BoF Aquaculture Site Policy & subjected to HADD regulations under the <i>Fisheries Act</i> – direct and indirect impacts from aquaculture occurring outside the MPA	Physical and biological features that influence the hydrologic regime, area ascribed to each ecotype	MPA regulations prohibit damage, destruction, alteration exception for Five Fathom Hole wharf & channel maintenance		
Area ascribed to different habitats (pelagic, benthic, nursery, spawning, migration pathways, marsh) and the % area and/or frequency disturbed or lost	<i>NB Submerged Land Policy</i> guides the protection & use of subtidal lands. Any disturbance of subtidal habitats due to human activities	Water quality levels, physical and biological features that influence the hydrologic regime	<i>Freshwater discharge from dam controlled by NB Power</i> may result in changes in salinity	Area ascribed to different habitats and the % area and/or frequency disturbed or lost	Permitted speed of vessels within Zone 2 no greater than 5 knots and in Zone 3 no greater than 8 knots (<i>Musquash Estuary MPA Regulations</i>). Wakes from speeding vessels can cause erosion
Water quality levels – done when required to determine the health of clam beds located within the Estuary	Monitoring of fecal coliform counts in water and clam beds done by ECW for EC when diggers request access to resource, none done when not needed				
Percent of primary biomass harvested	Dulse harvesting is permitted by hand, but no reporting or monitoring requirement is presently in place				

Table 3 (continued). Managed Activities in Musquash Estuary and their regulatory provisions (and other relevant monitoring) as they relate to the identified performance indicators.

Performance Indicator	Recreation, Tourism & Research	Performance Indicator	Watershed & Coastal Influences	Climate change
Estimates of human use/presence based on monitoring of all activities, mortality rates from hunting.	Hunting for mammals & birds (including migratory birds) regulated by <i>NB Fish & Wildlife Act</i> and the <i>Migratory Birds Convention Act, 1994</i>	Essential nutrient & phytoplankton concentrations, water turbidity levels	<i>Canadian Environmental Protection Act</i> regulates land-based sources of pollution	
% area ascribed to species providing biogenic structure	<i>Musquash Estuary MPA Regulations</i> prohibits the disturbance, damage, destruction or removal of a living marine organism or part of its habitat – would include tracks/trails in vegetated areas	Essential nutrient & phytoplankton concentrations, water turbidity levels; ratio of opportunistic species to other species	NB Water Quality Regulation under the <i>Clean Environment Act</i> prohibits water pollution	
Number of local populations or species at risk	SARA will apply if there is a species at risk	Number of local populations or species at risk	SARA will apply if there is a species at risk	
		Essential nutrient concentrations, water turbidity levels and phytoplankton concentration	<i>NB Natural Protected Areas Act</i> (Loch Alva) regulates certain activities in the Musquash watershed	
		Area covered by ecotypes present in the Estuary due to smothering; water turbidity levels	Any construction within 30 metres of a wetland requires a <i>NB Watercourse and Wetland Alteration permit</i> from NB DELG	
Area ascribed to different habitats and the % area and/or frequency disturbed or lost	Permitted speed of vessels within Zone 2 no greater than 5 knots and in Zone 3 no greater than 8 knots (<i>Musquash Estuary MPA Regulations</i>). Wakes from speeding vessels can cause erosion	Area covered by ecotypes present in the Estuary due to smothering. Essential nutrient concentrations, water turbidity levels and phytoplankton concentration	NB Coastal Areas Protection Policy guides coastal developments, NB <i>Clean Environment Act</i> prohibits water pollution	
		Essential nutrient concentrations, water turbidity levels and phytoplankton concentration	NB Power Coleson Cove emissions monitoring	
		Contaminant levels in sediment and bio-accumulated toxic levels in biota	NB <i>Clean Environment Act</i> prohibits water pollution & Can. Environmental Quality Guidelines (CCME)	

PRESENT HUMAN ACTIVITIES & MONITORING PROGRAMS IN MUSQUASH

WATERSHED AND COASTAL INFLUENCES - WATER SAMPLING

Discussion with Patrice Godin, Environmental Protection Branch, Shellfish Section, Environment Canada, Moncton (November 20, 2006)

Through a Memorandum of Understanding between Environment Canada (EC), Canadian Food Inspection Agency (CFIA), Department of Fisheries and Oceans (DFO), New Brunswick's Department of Environment and Local Government (NBDELG) and clam harvesters' associations, water quality and clam meat samples are collected and analyzed from areas that are of interest to harvesters. The principal objective of this sampling is to determine if the water quality is acceptable for the harvesting of shellfish (Richard et al. 2001). The request from clam harvesters is the first step in the process and is usually based on their assessment of the resource in a specific area. In the case of Musquash, the Lepreau Clam Harvesters Association (Wes Lomax) is usually the requesting group.

In the case of Musquash Estuary, there was no request from the harvesters for access to the beds located there and, as a result, there was no sampling done in 2006. In the present arrangement, diggers/harvesters pay for the entire cost of the analyses of the water and meat samples. Water quality and meat samples are collected under contract by Eastern Charlotte Waterways (ECW). Meat samples are analysed at Bedford Institute of Oceanography (DFO), while water samples are analysed at ECW for fecal coliform. It is a known fact that heavy rains result in increased fecal coliform in both the water and in the clams in Musquash Estuary. Environment Canada's Environmental Protection Service and CFIA provide technical advice to DFO with regard to water and clam meat quality. DFO is responsible for administering openings and closures of clam harvest areas.

Sampling around NB has been occurring since as far back as 1949. Data have been stored electronically since 1989 for Musquash Estuary. A shoreline re-evaluation of the actual and potential sources of pollution is conducted every 3 yr (Richard et al. 2001).

The demands of buyers from the United States for all facilities dealing with clams to be ISO (International Organization for Standardization) accredited means that it is less likely that this sampling program will be amenable to allow participation of trained community volunteers; however, taking a water sample is a simple process while the analysis is done in a laboratory. Water sampling is done from a boat in sterile wide mouthed polyethylene bottles at a depth approximately 20 cm below the water surface. At the time of sampling, salinity, air and water temperatures are recorded. Rainfall data are recorded at Coleson Cove.

WATERSHED AND COASTAL INFLUENCES/CLIMATE CHANGE - AIR QUALITY MONITORING

From: Coleson Cove Generating Station Refurbishment Project: Environmental Impact Assessment Draft Report, April 5, 2002. NB Power Corporation.

NB Power presently monitors the emissions of combustion gases and particulate matter from the Coleson Cove Generation Station. The emissions of nitrogen oxides, carbon monoxide and oxygen are monitored using a continuous emissions monitoring (CEM) system. The emissions of sulphur dioxide are monitored using a Software Continuous Emission Monitoring (SCEM) program. There are also continuous opacity monitors downstream of the electrostatic precipitators. Supplemental monitoring is done by source emission testing and annual stack testing for particulate emission as well as for nitrogen oxides and sulphur dioxide. Modeling shows that the Musquash Estuary MPA and salt marshes are within the zone of influence of emissions from the generating station.

FISHERIES RELATED - FINFISH FISHERY

Recreational fishery by means of angling, dip nets, or by hand picking in accordance with the *Atlantic Fishery Regulations, 1985* or the *Maritime Provinces Fishery Regulations*, is permitted within the Musquash Estuary. While the recreational fishery in the Estuary is limited, there are presently no reporting requirements. From a monitoring perspective, however, it would be beneficial to record the species, size and the number of individuals captured and removed by this activity.

Commercial fishing for elvers or eels by means of a hand-deployed fyke net or dip net is permitted as long as the activity is in accordance with the *Atlantic Fishery Regulations, 1985* or the *Maritime Provinces Fishery Regulations*. There is presently only one license holder who fishes for elvers in the Musquash Estuary in two locations, upstream of the Highway #1 bridge (Musquash River West) and upstream to the New Brunswick Power Plant (Musquash River East). The license conditions permit the use of dip nets, elver traps and elver pots, but only four traps or pots in combination can be deployed at any one time in any river. There is a restriction on the weight (300 kg) of elvers that can be taken from any river. There is also a reporting requirement for Dockside Monitoring Company to record the total weight of elvers caught on any day the catch is taken. In addition, the license holder is required to maintain daily catch and effort records in an Elver Fishery Logbook which is turned into the Population Ecology Division at Bedford Institute of Oceanography (BIO) every year. The logbook requires information on the date, fishing gear, number of gear units, hours fished per gear unit and catch in kilograms. In addition to the actual catch taken, it would be beneficial to obtain data to track the status of the eel spawning and breeding components within the Estuary.

Commercial fishing for herring in Zones 2A, 2B and 3 (Fig. 1) is also permitted by a weir, beach seine, bar seine or drag seine in accordance with these regulations. There is presently one inactive herring weir in the White Rocks area on the western shore of the Estuary. No herring weirs have operated in the area since 1987

(Thompson 2000); however, if there is a restart of this fishery, records of landings/catch in the Estuary should be reported.

FISHERIES RELATED - LOBSTER FISHERY

From: Conditions for lobster licenses issued by DFO.

Commercial fishing within the Estuary is allowed for lobster by means of individual traps in Zones 2A, 2B and 3 (Fig. 1). During the fall fishing season (November-December), about 12 vessels fish traps in the area of Gooseberry Island and across the mouth of the Estuary, while the spring fishery involves about six vessels (Thompson 2000). In the lobster license conditions, there is no specific statement with respect to the reporting of catches of lobsters and male rock or Jonah crabs from a specific location. Instead, catches are reported for a specific port from which the catch is unloaded. In order to monitor the catches within the Musquash Estuary MPA, it will be essential that the license conditions reflect the need to record all the catches, as well as all the by-catch from within the MPA boundaries. This would require some sort of agreement with fishers to record all the relevant information of their fishing activities when in the MPA. Such information would include the location of traps or trawls, the number of traps, details of all species caught (may also need to record the size of the individuals caught and retained, as well as those released as by-catch).

FISHERIES RELATED - CLAM FISHERY

From: Conditions for clam licenses issued by DFO and Conservation Harvesting Plan 2003-2005.

This license cover the soft-shelled clam (*Mya arenaria*), the razor clam (*Ensis directus*), the bar clam (*Spisula solidissima*) and the bay quahog (*Mercenaria mercenaria*). The species of interest in Musquash Estuary would be the soft-shelled clam in all the management zones (Fig. 1). As previously mentioned, the access to this fishery within the Estuary is dependent on the abundance of the resource as estimated by the diggers association, followed by a request for fecal coliform analysis. Approval is done through the Environment Canada Shellfish Water Quality Protection Program and once the stocks are considered safe, harvesting is done by the diggers using hand-held clam hoes. There is a self-reporting system in place for the fishery. Licensed commercial diggers are required to record and report their name, the name of the local beach, the date and the estimated weight of clams caught. In the case of the protected area, it may be necessary to request from diggers an estimate of the area dug up or searched for clams. This would provide an estimate of the area disturbed. There appears to be no size restriction because no mention of size is indicated in the License Conditions for commercial harvesters. However, under recreational harvesting, a person may, without being registered or licensed, harvest soft-shell clams by hand or with the hand-held tools in open areas but will be restricted to a possession limit of one hundred (100) clams and a size limit of 44 mm.

FISHERIES RELATED - ROCKWEED HARVESTING

From: 2006 Rockweed Harvesting License

Musquash Estuary is considered by DFO and Acadian Seaplants (the only rockweed harvesting licensee in New Brunswick) as a long-term reference area (LTRA) and no harvesting is permitted in a long-term reference area at any time. Acadian Seaplants has been a long time supporter of the Musquash Estuary MPA. As stated in the *Musquash Estuary MPA Regulatory Impact Analysis Statement* (Canada Gazette Part II, Vol. 140, No. 26, 2006), the rockweed industry (Acadian Seaplants) is prepared to concede this area for protection and, as a result, the area will be protected from any future rockweed harvesting operations.

FISHERIES RELATED - DULSE HARVESTING

Recreational and commercial harvesting of dulse by hand is expected to continue in the Musquash Estuary in Zones 2A, 2B and 3. Commercial harvesting occurs on an irregular basis (Thompson 2000). There is currently no management plan and no license is required for the harvesting of dulse. With the designation of the area as a MPA, however, it will be necessary to implement some sort of monitoring and reporting system for this species. Data would be needed on the location of harvesting areas, the dates of harvesting operations, the man-hours spent harvesting and some estimate of the quantity (wet weight) of the harvest. Monitoring would be needed to track the status of the resource over time and to ensure that the ecosystem objectives and sub-objectives are being attained.

FISHERIES RELATED - SCALLOP FISHERY

From: 2006 Bay of Fundy Mid and Upper Bay Scallop Fleets, Conservation Harvesting Plan

All vessels are required to report number of tows, average tow time, depth, bottom type and catch using the Dockside Monitoring Documents and Logbooks. All scallop fishing vessels are to have a DFO-approved Vessel Monitoring System on their vessel that can be actively tracked by a Vessel Monitoring Station. Within the Musquash Estuary MPA, scalloping will be allowed only in Zone 3 (the scallop zone) (Fig. 1). Scallop dragging is usually carried out in this area from mid-January through to March, and usually when weather conditions do not permit boats to go elsewhere (Thompson, 2000). It would be beneficial from a monitoring point of view to have some sort of agreement with fishers to voluntarily record and report all the relevant information of their fishing activities when in Zone 3. Some measures/records of the catch, bycatch and bycatch mortality may be needed to track estimates of the abundance of scallop and bycatch species over time.

FISHERIES RELATED - PERIWINKLE HARVESTING

In the Musquash area, this is mainly a recreational fishery with irregular commercial harvesting (Thompson 2000). There are presently no regulatory provisions to deal with this activity. It would be necessary to implement some sort of monitoring and

reporting measures within the Musquash Estuary for periwinkle harvesting in order to obtain estimates of the quantity of periwinkles being removed by recreational harvesters and the irregular commercial harvesters. Monitoring would be needed to track the status of the resource over time.

RECREATION, TOURISM AND RESEARCH – HUNTING

Hunting occurs throughout the marshes and woodlands surrounding the Musquash Estuary. In the fall, deer, moose, ruffed and spruce grouse, various species of duck and snowshoe hare are hunted (Thompson 2000). During October, heavy duck hunting occurs in and around the Ducks Unlimited impoundments. Hunting for mammals and birds (including migratory birds) is regulated by *NB Fish & Wildlife Act* and the *Migratory Birds Convention Act, 1994*. All deer and moose harvested are required to be reported to the NB Department of Natural Resources.

RECREATION, TOURISM AND RESEARCH - HUMAN TRAMPLING

There is no estimate of the possible impact that human trampling would have on the intertidal communities within the Musquash Estuary MPA. There is presently a fairly low number of visitors to the area; hence, the impact can be assumed to be low. With the Estuary becoming a MPA, the area may become a popular recreational destination, leading to increased recreational pressure. As a result, it may be necessary to obtain estimates of visitors and the amount of area being trampled. It has been demonstrated elsewhere that trampling on rocky shores generally causes considerable reduction in density and cover of both sessile invertebrates and algae (see Casu et al. 2006). As a result, the vulnerability and resilience of shallow zoobenthic communities should be considered in any management plan once the number of visitors increases.

WATERSHED AND COASTAL INFLUENCES – GENERAL

It is important to note that activities on the adjacent land and watershed can threaten and cause damage to the ecotypes present in the Estuary. Activities that result in the release of sewage, siltation, coastal pollution and run-off from the land can lead to degradation of the Estuary. The management and objectives of the MPA, therefore, should be closely linked to overall planning for the coastal zone (Sumaila et al. 2000). Sections of the forested areas in the Musquash watershed are already under some sort of protection. It is envisioned that Musquash Estuary will become part of a larger Coastal Management Area (CMA) that will include monitoring the human activities occurring within the watershed.

INDICATORS FOR USE IN MONITORING PROGRAM

A single human activity can be expected to have multiple impacts on a species, community or ecotype. For example, to maintain the marsh and mudflats, there must not be any alteration to the flow and circulation patterns of the waters within the MPA. Hence, changing the physical dimensions of the channel at Five-Fathom Hole would result in alteration flow conditions resulting in reduced flows and possibly increased velocity and changed patterns of the currents and sedimentation on the seaward side (Parker and Rutherford 2005, Singh and Buzeta 2005). Hence, any proposed activity that would result in changes in the hydrologic regime in the Estuary will need to be evaluated and monitored very carefully.

Monitoring is defined by Hellawell (1991 cited in Finlayson and Mitchell 1999) as a systematic collection of data or information over time to ascertain the extent of compliance with a predetermined standard or position. In the case of Musquash Estuary MPA, it is to ensure that the ecosystem objectives as set out in Table 2 are being met. Some additional reasons for monitoring include: to collect baseline data, to characterize variations in response due to natural variability, to record natural or human-induced ecological changes, and to determine whether management objectives are being met (Finlayson and Mitchell 1999).

Since it is impossible to measure and interpret all the factors and variables that interplay in ecological issues, a monitoring program must select indicators that measure the most valued ecological components and those that are responsive to a variety of stressors (Kurtz et al. 2001). The selection of indicators in the case of Musquash Estuary MPA is very much linked to the ecological objectives. Considering the possible human impacts on the MPA, the indicators selected must be able to provide data that show a response to the impacts if and when they occur. As a result of the approach used in developing the objectives, a series of performance indicators were identified in Table 2. These performance indicators were selected based on expected impacts and considering attributes of the impacted ecological resource or function that are measurable.

When evaluating an ecological indicator, Kurtz et al. (2001) recommended that the focus should be on four fundamental questions:

- Is the indicator relevant to the management concern and to the ecological resource or function at risk?
- Are the methods of sampling and measuring the indicator technically feasible, appropriate, and efficient for use in the monitoring program?
- Are the errors of measurement and natural variability over time and space sufficiently understood and documented?
- Will the indicator convey information on ecological condition that is meaningful to environmental decision making?

As stated before, the baseline data for some of the performance indicators identified in Table 2 may be available from the literature, but for many of them the initial measurements will form the baseline data. As a result, it may take several years to determine the natural variability over time and space sufficiently to be able to determine if change is occurring. This reinforces the need for a baseline survey of the area, a need that was previously identified (Singh and Buzeta 2005). In addition, since monitoring is both a research and a management tool, it is essential that an adequate information base be obtained by implementing a systematic monitoring program (Finlayson and Mitchell 1999) as soon as possible.

The performance indicators listed in Table 2 will form the basis of the list of indicators that would become part of the Monitoring Plan. The indicators listed may respond to potentially more than one variable or stressor, and hence would help determine whether more than one ecosystem sub-objective was being met. An indicator may be selected, even if it has weaknesses, if it provides important information (Kurtz et al. 2001). In examining the impact of human activities, it is essential to consider the necessary background information on individual species. Information on the life-history characteristics of species as outlined in Singh and Buzeta (2005) are needed to interpret the likely impact of human activities on species, and to determine whether the survival of a species or ecotype is being put at risk (Hiscock and Tyler-Walters 2006). The possible impacts from human activities can be classified under three broad categories: physical, chemical and biological. Figure 2, adapted from Hiscock and Tyler-Walters (2006), shows how the impacts of human activities may influence a management response based on the outlined ecosystem framework.

The terminology used in Fig. 2 will have to be defined, since it can lead to different interpretations. In order to determine if an activity is likely to impact species, communities, habitats or ecotypes, it will be essential to consider the life-history characteristics of the species in the potential impact area (Singh and Buzeta 2005, Appendix 2). The information provided in life-history characteristics tables can be used to determine the "sensitivity" of individual species, or groups of species, to physical, chemical or biological disturbances. The resulting assessment will need to be fed back into the management process to assist in evaluating whether the management response taken was appropriate or needs to be changed (adaptive management). The management objectives and the accompanying ecosystem objectives should determine what data are collected in the monitoring program. Additionally, the monitoring program should provide the basis for the continuation or modification of the management program (Finlayson and Mitchell 1999). Hence, the next version of the management plan will be guided by the feedback obtained from the monitoring cycle. The monitoring and performance assessment regimes will be used to determine whether the intended conservation and management objectives are being achieved (Sainsbury and Sumaila 2003).

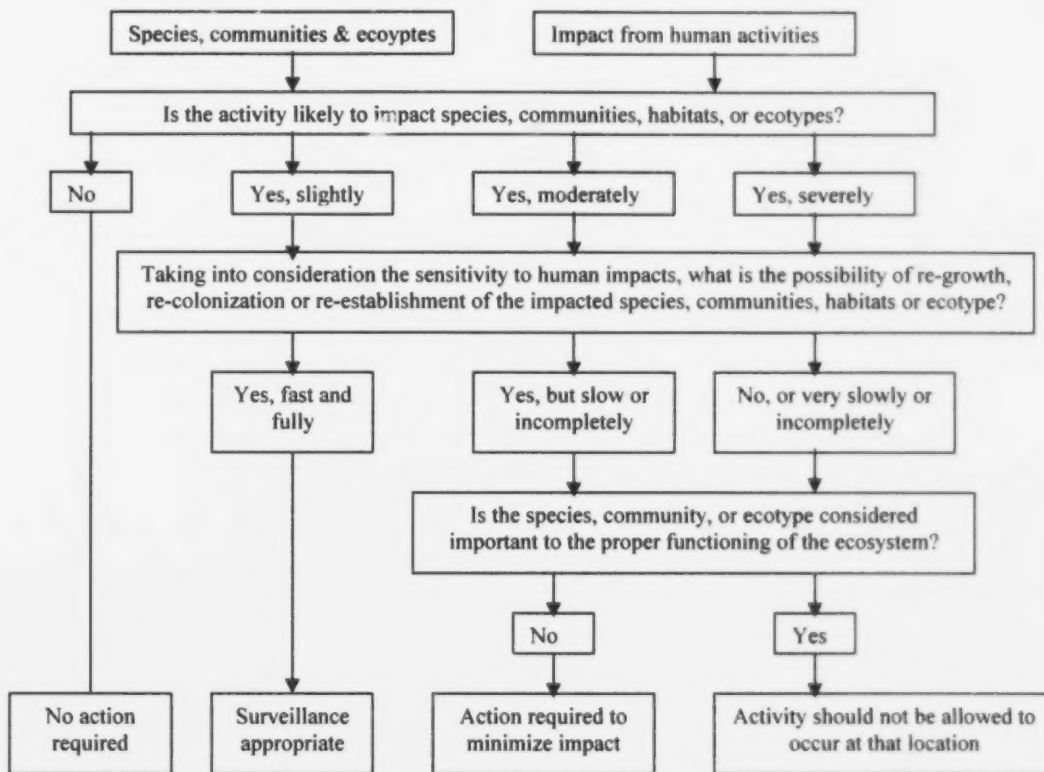


Fig. 2 A decision tree for human induced impacts and management response (adapted from Hiscock and Tyler-Walters 2006) based on the outlined ecosystem framework.

Table 4. Performance indicators identified in Table 2 and their suggested monitoring requirements. The similar shading intensities identify the same monitoring requirements for the corresponding performance indicators.

Performance Indicators: Biodiversity	Suggested Monitoring Requirements
% area of Estuary ascribed to each ecotype in each zone & location in Estuary	GIS mapping of the various ecotypes within the Estuary. Frequency: Once every 3-5 yr?
Present number of species in each trophic level & abundance of keystone species	Annual surveys of all species present in each ecotype by use of transects, sampling. Visual surveys where appropriate.
Present numbers & distribution of exotic species in MPA in relation to Regional data	Visual surveys (annually) and GIS mapping (every 3-5 years) of exotic species, some estimate of exotics in the Region
Present numbers of distinct viable populations for a species within the Estuary	Annual sampling of size/sex/age in capture fisheries (e.g. eels, lobster, scallops, clams) and for species in areas impacted by human activities
Present number of local populations at risk	Local populations at risk to be determined from numbers present obtained via sampling.
Present number of species within each ecotype	Annual survey of all species present in each ecotype by use of transects, sampling. Visual surveys where appropriate.
Ratio of opportunistic species to other species	Species present obtained from annual surveys and determination of their ecological and trophic roles
% bycatch, absolute bycatch, bycatch mortality rate, abundance of impacted species	Monitoring and reporting of bycatch and bycatch mortality rates and the harvested species (numbers/weight)
Performance Indicators: Productivity	
Essential nutrient concentrations, historic water turbidity and phytoplankton concentration	Physical properties of water (at least once during each season) and concentration of phytoplankton (at least once during summer).
Trophic levels present in each ecotype & estimates of biomass & spatial distribution	Survey of all species present in each ecotype by use of transects, sampling and visual surveys (annually).
Total catch biomass for harvested species	Reported harvested species (numbers and weight)
Mortality rate from fishing activities	Monitoring and reporting of bycatch and bycatch mortality rates and the harvested species (numbers/weight)
% bycatch; bycatch mortality rate; absolute bycatch, abundance of impacted species	Monitoring and reporting of bycatch and bycatch mortality rates and the harvested species (numbers/weight)
Estimates of numbers of juvenile fish & bird hatchlings occurring in the MPA	Bi-annual survey for juvenile fishes and for bird hatchlings
Estimates of biomass changes	Annual estimates of biomass removed by human activities
% size/sex/age in catch & in areas impacted by activities	Annual sampling of size/sex/age in capture fisheries (e.g. eels, lobster, scallops, clams) and for species in areas impacted by human activities
Estimates of human use/presence based on monitoring of all activities	Monitoring of all human use/presence through permits, licenses and visitations to the Estuary
Discarded catch	Monitoring of all discarded catch
Performance Indicators: Habitat	
Area ascribed to different habitats and the % area and/or frequency disturbed/lost	GIS mapping of the various ecotypes within the Estuary. Frequency: Once every 3-5 years?
Present contaminant levels in sediment and bio-accumulated toxic levels in biota	Regular contaminant level estimates in sediment and tissues in selected biota
% area ascribed to species providing biogenic structure	Species providing biogenic structure and their areal extent from GIS mapping (once every 3-5 yr)
Historical & present water turbidity levels	Physical properties of water (at least once during each season)
Historical & present water quality levels	Physical properties of water (at least once during each season)
Historical & present physical/biological features that influence the hydrologic regime	Annual surveys of the physical and biological features that influence the hydrologic regime, closer monitoring of activities approved that can change the hydrologic regime

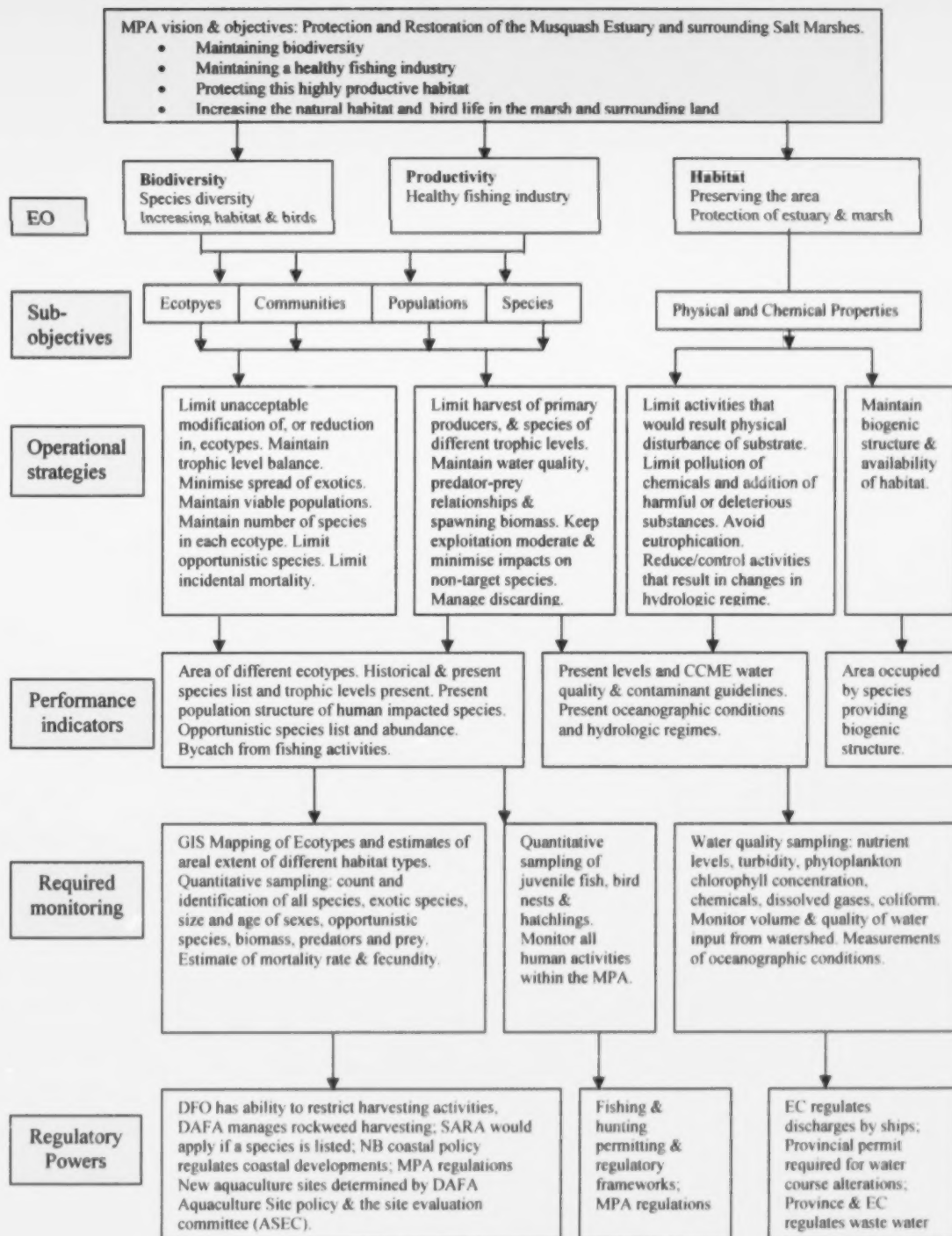


Fig 3. Visual presentation of the Musquash Estuary MPA ecosystem framework as described in this document.

CONCLUSION

NEXT STEPS

It is expected that the framework and the identified monitoring requirements as described in this document will require a peer review process. Such a review will evaluate the ecosystem objectives and sub-objectives as identified for the Musquash Estuary MPA. It is recognized that a major challenge will be the identification of cause and effect (Gislason et al. 2000). The review process will also look at the monitoring that would be required and evaluate the usefulness in determining whether the objectives are being met. It will be necessary also to refine the proposed performance indicators to ensure that they are both precise (e.g. % ecotype area or % ecotype area disturbed) and measurable (e.g. number of species in each trophic level) to ensure that they are practical and can be made operational. The process may also be used to identify other less costly measurable indicators that may serve the same purpose as originally intended. The suggested monitoring requirements for each performance indicator, and the methodology to be used, would also be identified and evaluated at this stage. It is also expected that the candidate reference points would be identified for all the performance indicators and there would be a need to have stakeholder consultation to establish those reference points.

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DEFINITIONS

(From Jamieson et al. 2001)

Conceptual Objective: stated in general terms and intended to be understandable to a broad audience. Policy statements by a government or an organization, for instance, can be considered conceptual objectives. They are broad statements and can be interpreted differently by different people. They lack specificity to be operational.

Operational Objective/Strategy: Objective that has a direct and practical interpretation in the context of (fisheries) management and against which performance can be evaluated quantitatively. An Operational Objective consist of a verb (e.g., maintain), a specified measured indicator (e.g., biomass), and a reference point (e.g., 50,000 t), thus allowing an action statement for management (e.g., maintain biomass for a given forage species > 50,000 t).

Reference Point: Value of an indicator corresponding to a management target or threshold. Note: operational objective, indicator, performance measure and reference point form a package. Each of the three elements of the package is essential to properly define and interpret an indicator.

Indicator: Quantity that can be used to measure and track changes over time with respect to an operational objective.

Performance Measure: Function that converts the value of an indicator to a quantitative measure of management performance with respect to the operational objective (usually by comparing the indicator to a reference level or point).

Characteristic: Biological property of the ecosystem, separate from our measurement of it. For instance, recruitment is a characteristic of a fish population. Survey age one numbers per tow or survey number numbers from a population analysis might be the associated indicator.

